Dipartimento di Fisica e Astronomia Galileo Galilei

Università degli Studi di Padova

Osservatorio Astronomico di Padova

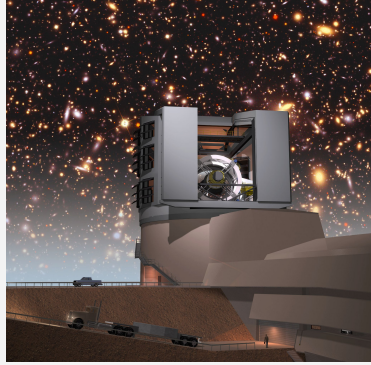
Investigating the star formation history of nearby galaxies

Alessandro Mazzi
PostDoc @ Università di Padova, Italy

Overview

1. Rubin LSST
2. SFH recovery
3. The resolved SFH of the LMC - Mazzi et al. 2021
4. Adding the spatial correlation
5. Conclusion & future prospects

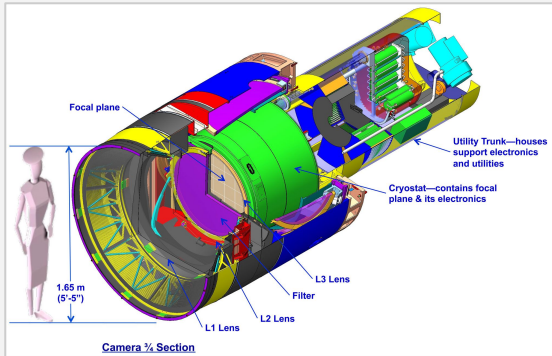
Rubin LSST



https://www.lsst.org/science

- All sky below δ=34.5°
- Fov of 9.6 deg^2, covered by 3.2 Gigapixels (189 CCDs)
- Seeing-limited image quality across a wide wavelength interval (320-1050 nm)
- Single visit typical 5σ depth in r ~24.5 mag
- After 10 years precise parallaxes for sources deeper than Gaia's limit

- Milky Way
  - Solar neighborhood
  - Disk, Halo, Bulge
  - Clusters
- Streams
- Magellanic Clouds
- Dwarf galaxies (Sagittarius, …)
- …



Star formation history (SFH) recovery

How many stars have formed at a given age?

What is their metallicity?

How many are in binaries?

What is their mean extinction?

What is their mean distance?

...

Simple stellar populations

Compute partial models at several ages

$$M_i = M(t_i, [\mathrm{Fe/H}]_i, f_{\mathrm{bin}}, A_{\mathrm{V}}, d)$$

For a given set of parameters

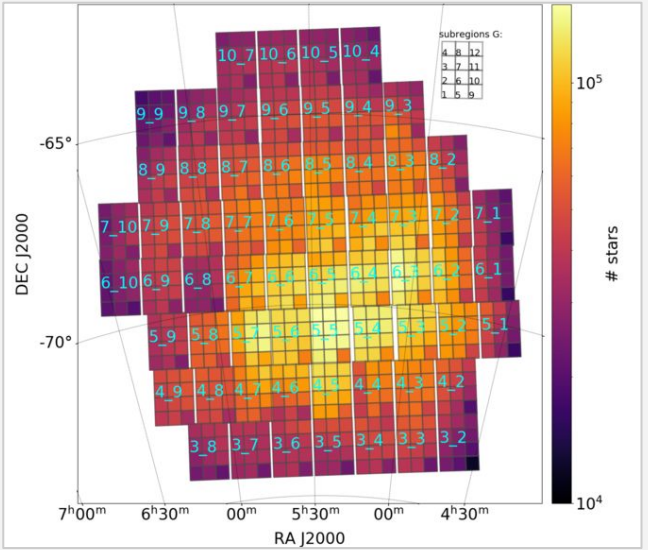
$$M = \sum_{i=0}^{N_{\mathrm{ages}}} \mathrm{SFR}_i * M_i$$

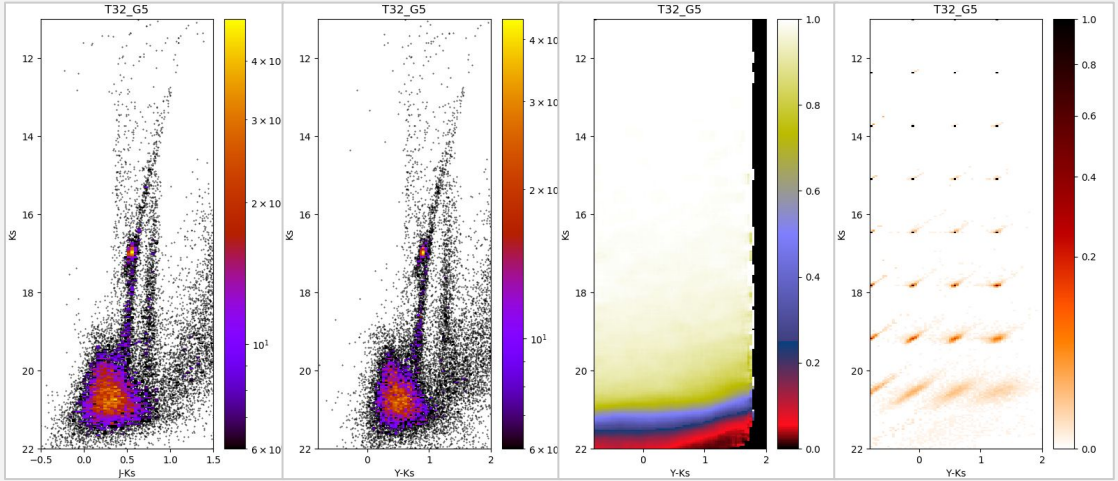
Fit to observations to get the set of best parameters

The resolved SFH of the LMC

Mazzi et al. (2021)

- Deep PSF photometry in Y, J and Ks for 105 deg^2 from the VMC survey (Cioni et al. 2011)
- 63 tiles, 12 sub-tiles each → 756 separate regions
- Hess diagrams (0.04 mag bins)
  - 11< Ks< 22 mag
  - -0.5 < J-Ks < 1.5 mag
  - -0.8 < Y-Ks < 1.2 mag
- Completeness and errors from artificial star tests



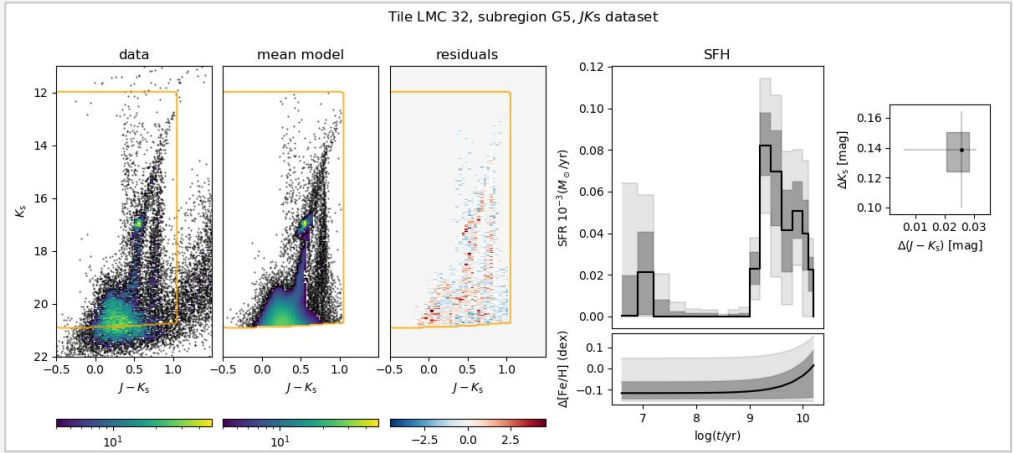


The resolved SFH of the LMC

Mazzi et al. (2021)

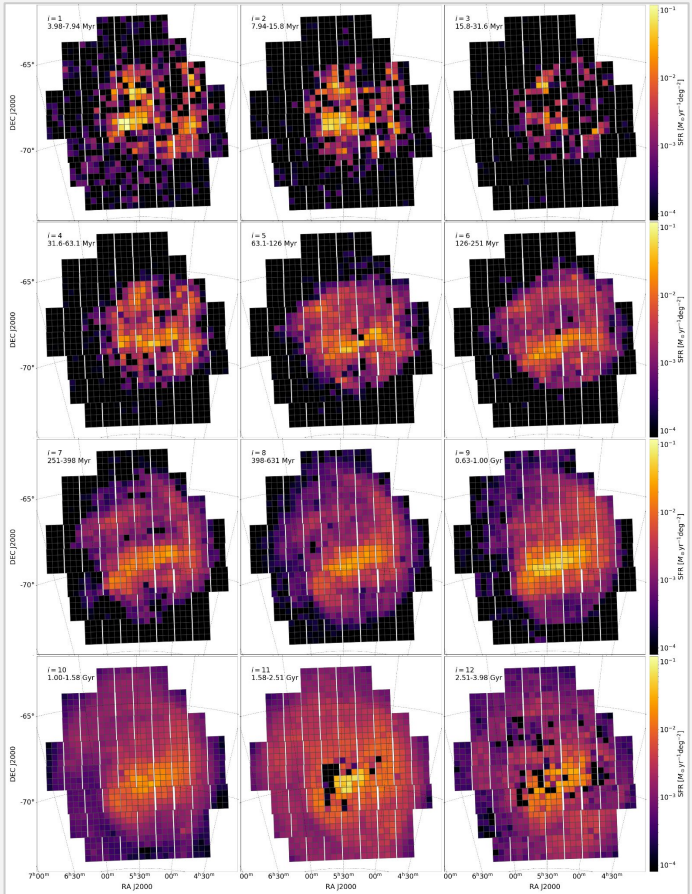
- Synthetic models produced with TRILEGAL (Girardi et al., 2005)
  - Kroupa IMF
  - 16 age bins
  - Convolution with errors from AST
  - Milky Way foreground
- Only consider 12< Ks < mag@75% completeness
- Two step fitting
  - Nelder-Mead optimization (only SFR)
  - Markov chain Monte Carlo (all parameters)
- Parameters
  - 16 SFR
  - 3 [Fe/H]
  - magnitude shift (distance+A_V)
  - color shift (A_V)

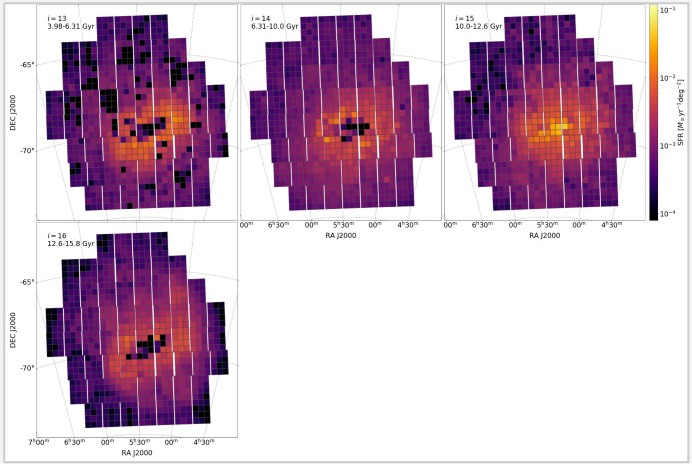
i	log (t/yr)	Δt (yr)	$[Fe/H]_0$ interval (dex)
1	6.6, 6.9	3.96×10^6	−0.19, −0.19
2	6.9, 7.2	7.91×10^6	−0.19, −0.19
3	7.2, 7.5	1.58×10^7	−0.19, −0.19
4	7.5, 7.8	3.15×10^7	−0.19, −0.19
5	7.8, 8.1	6.28×10^7	−0.19, −0.19
6	8.1, 8.4	1.25×10^8	−0.19, −0.19
7	8.4, 8.6	2.50×10^8	−0.19, −0.19
8	8.6, 8.8	2.32×10^8	−0.19, −0.19
9	8.8, 9.0	3.69×10^8	−0.19, −0.19
10	9.0, 9.2	5.85×10^8	−0.19, −0.25
11	9.2, 9.4	9.17×10^8	−0.25, −0.36
12	9.4, 9.6	1.47×10^9	−0.36, −0.49
13	9.6, 9.8	2.33×10^9	−0.49, −0.60
14	9.8, 10.0	3.69×10^9	−0.60, −0.95
15	10.0, 10.1	2.59×10^9	−0.95, −2.07
16	10.1, 10.2	3.26×10^9	−2.07, −3.18

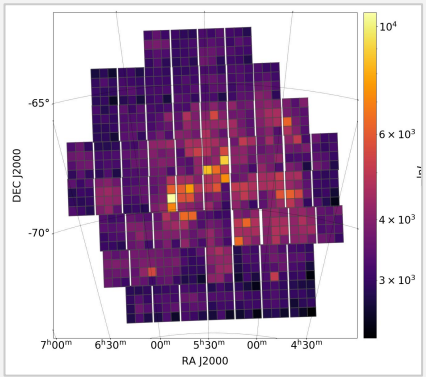


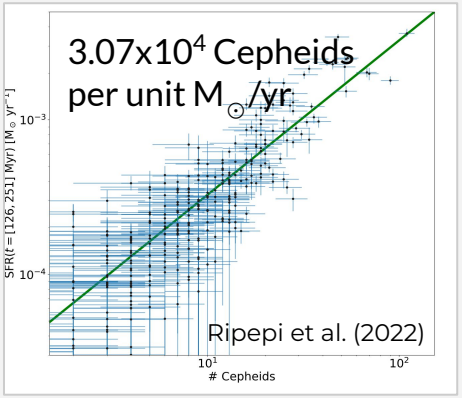
The resolved SFH of the LMC

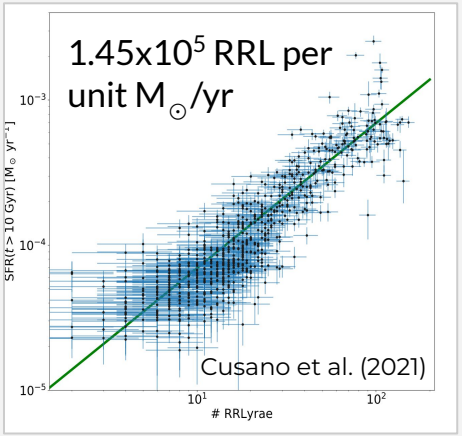
Mazzi et al. (2021)







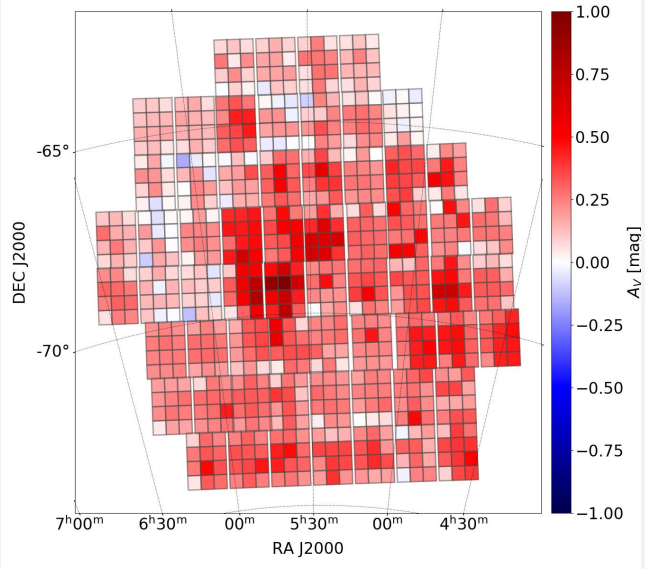




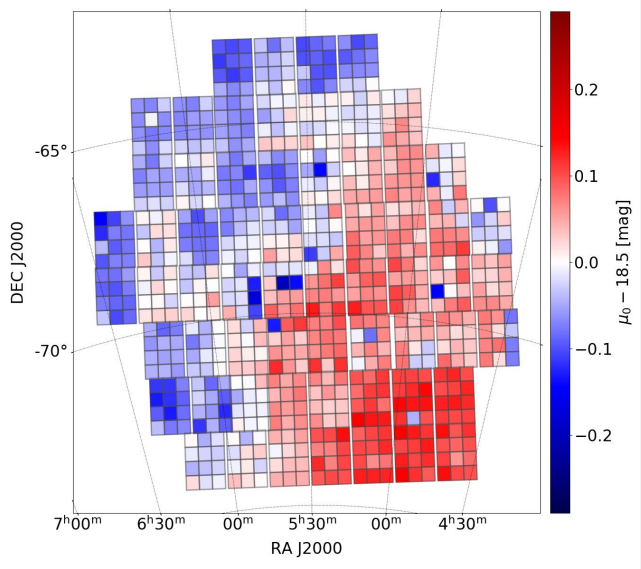
The resolved SFH of the LMC

Mazzi et al. (2021)

Extinction



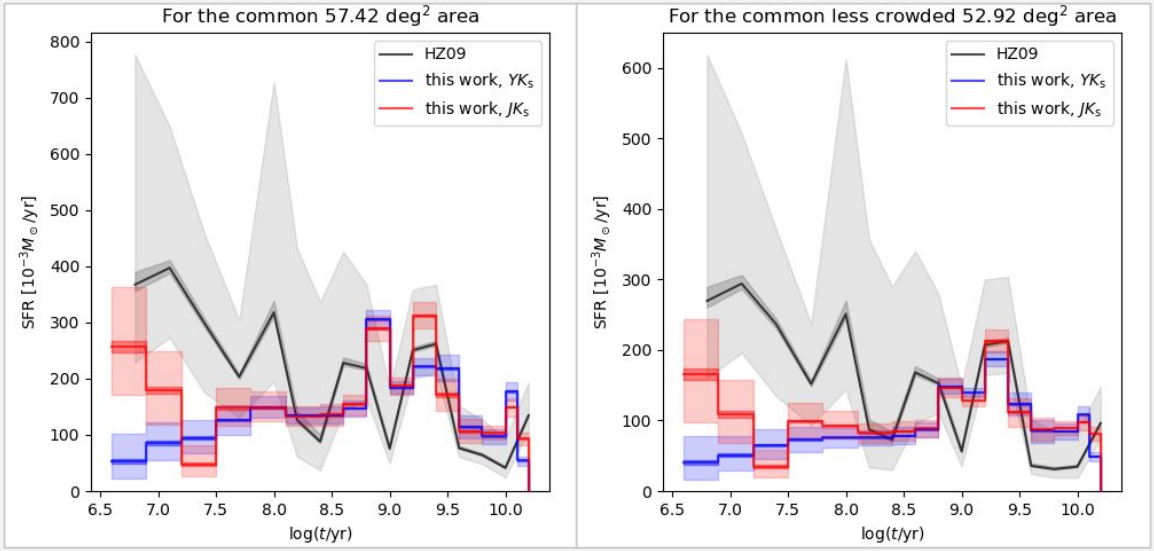
Distance shift

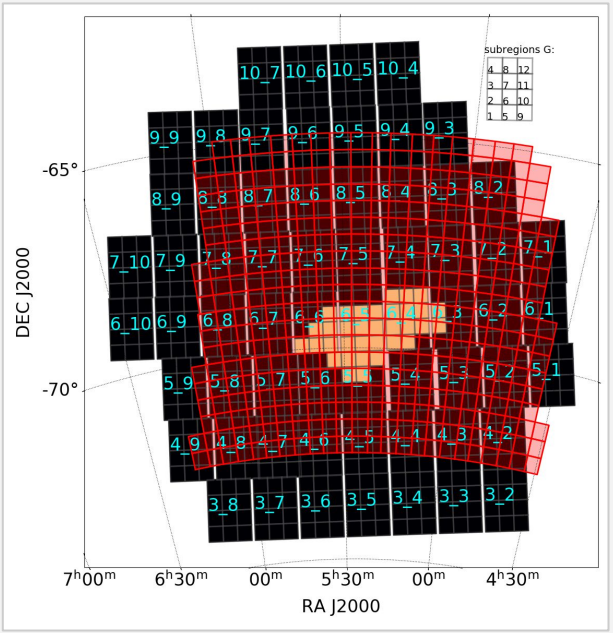


The resolved SFH of the LMC

Mazzi et al. (2021)

Comparison to Harris & Zaritsky (2009) [resampled]





Adding the spatial correlation

Why?

Old population should have smooth distribution, young one should be clumpy instead

Change SFR prior to correlated one (gaussian process)

$$P(\theta_1, \ldots, \theta_n) = \frac{\exp\left(-\frac{1}{2}(\boldsymbol{\theta}-\boldsymbol{\mu})^{\mathrm{T}} K^{-1}(\boldsymbol{\theta}-\boldsymbol{\mu})\right)}{\sqrt{(2\pi)^n |K|)}}$$

Multivariate Gaussian

$$K_{i,j} = k(\mathbf{r}_i, \mathbf{r}_j) = \sigma^2 \exp\left\{-\frac{|\mathbf{r}_i, \mathbf{r}_j|^2}{l^2}\right\}$$

Kernel

Correlation length

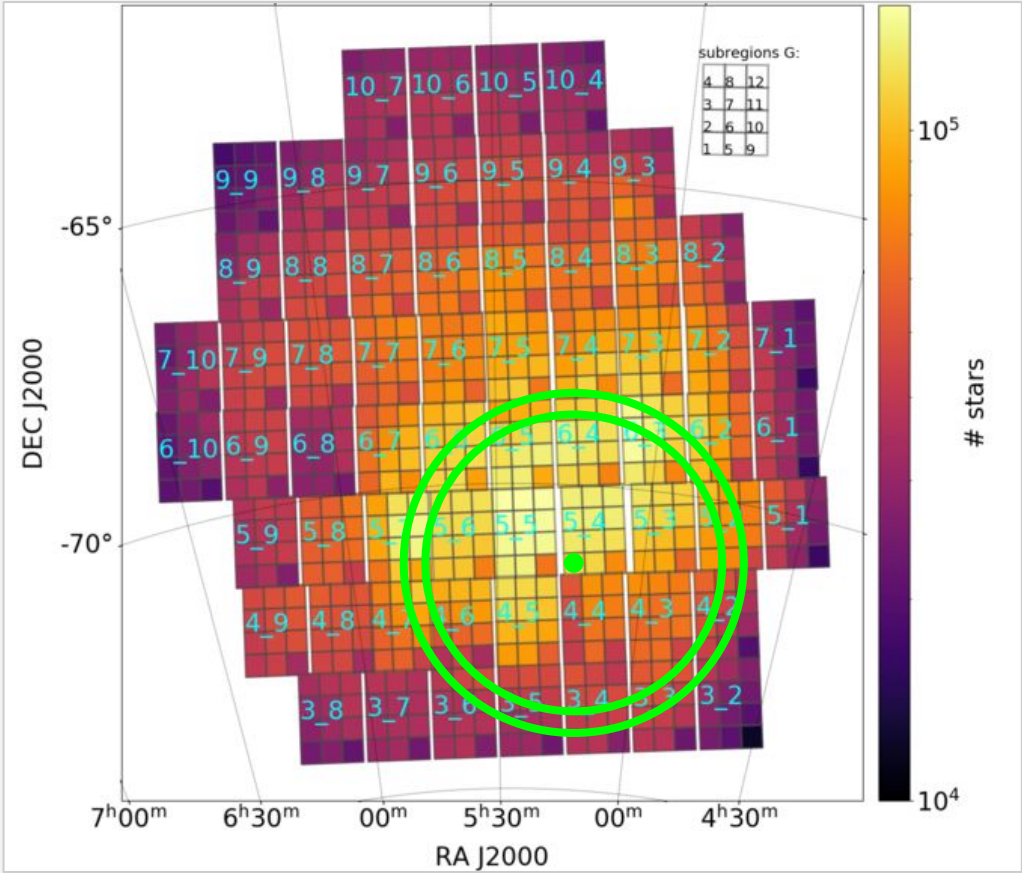
Age dependence

$$l = l(\mathrm{age}) = ?$$

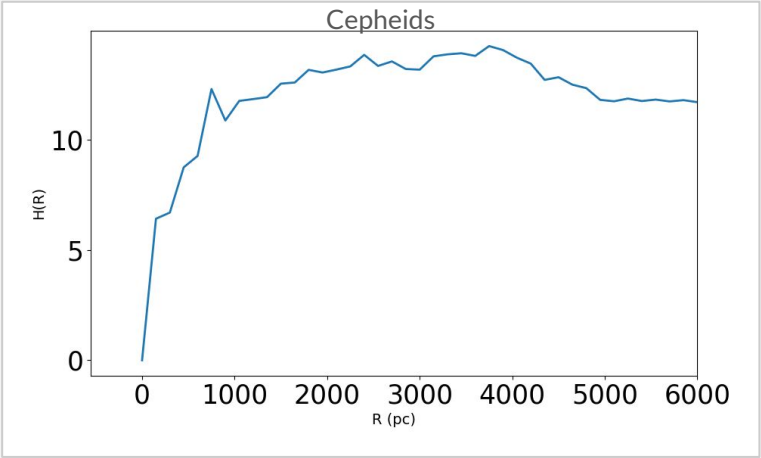
Adding the spatial correlation: in the data?

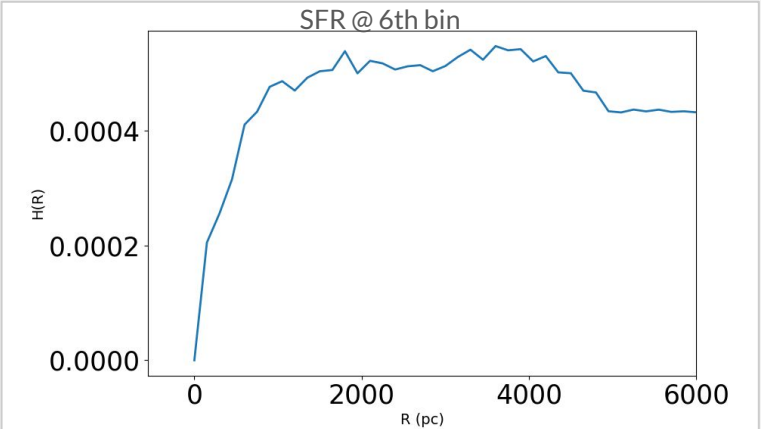
$$K(d) = \sqrt{\frac{\sum_{i=0}^{M} \left(N_i - N_i(d)\right)^2}{N_{tot}(d) + 1}}$$

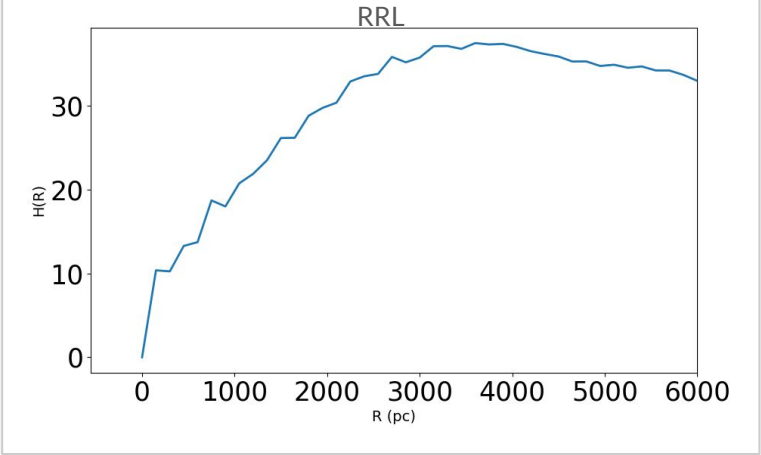
$$N_{tot}(d) = \sum_{i=0}^{M} N_i(d)$$

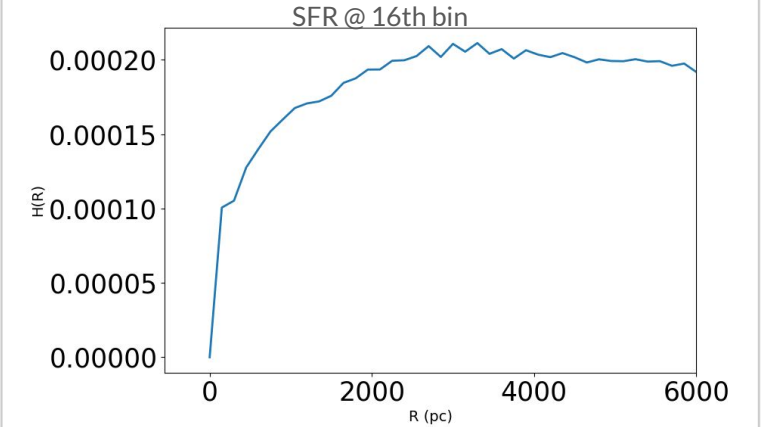


Adding the spatial correlation: in the data?









Conclusions

- LSST will produce high quality photometry over a large portion of the sky
- Targets:
  - Milky Way
  - LMC & SMC
  - Local Group galaxies
- Current resolved SFH recovery methods might provide very noisy results
  - SFR holes
  - Extinction
  - Distance
- Add correlation to smooth the result
- Required:
  - Deep photometry of the stacks
  - AST of area of interest
  - Task force crowded field photometry

- Who we are working with
  - Julianne Dalcanton
  - Rodrigo Luger
  - Morgan Fouesneau
  - Gregory Green

THANK YOU!